Study of copper connections uncovers route to improving the reliability of electronic devices

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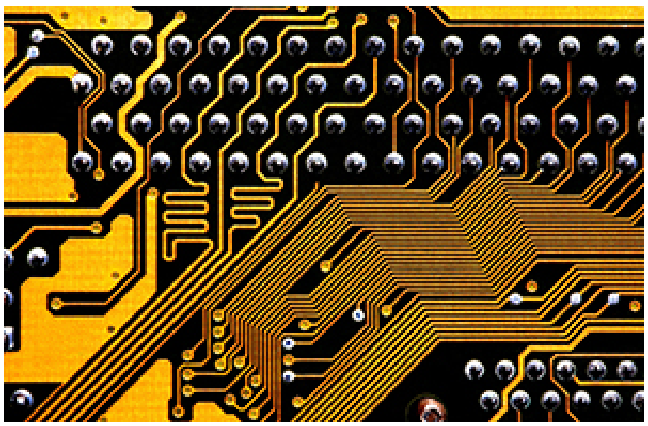

Understanding how corrosion affects the reliability of the bonds connecting components on an integrated circuit could help to increase the operational lifetime of microelectronic devices. Credit: Joao Freitas/Hemera/Thinkstock

One in five electronic-device failures is a result of corrosion. Bonds, the metal connections that enable the current to flow from one component to the next (see image), are a particular weak point. Understanding what causes this breakdown is important for extending the lifetime of a device. Kewu Bai and co-workers at the A*STAR Institute of High Performance Computing, Singapore, have charted how moisture can affect the stability of the bonding and developed a scheme for improving the reliability of these connections.

Wire bonding is generally considered the most cost-effective and flexible method for interconnecting an integrated circuit or other semiconductor device and its packaging. "This process uses force, ultrasonic vibrations and heat to make bonds," explains Bai. "The reliability of the bonds depends on the stability of the metallic compounds that form during the process of connecting a contact pad—made from aluminum, for example—and the wire, which is made of copper or gold."

Gold is the material of choice for electrical connections in microelectronic components. With the price of gold having steadily risen over the last few years, however, electrical engineers are now turning to copper as a cheaper alternative because it exhibits many of the same desirable electrical properties. As copper–aluminum compounds are prone to corrosion in humid environments, encapsulation is employed in microelectronic packages to prevent moisture ingress, yet permeation and leakage are still possible. Damage to the external packaging can allow moisture to reach the sensitive circuitry and slowly corrode the copper connections.

"Using simulations, we can understand the conditions for copper wire bonding corrosion in aqueous environments and the corresponding corrosion mechanisms," says Bai. "There has been much debate about the possible mechanisms for a long time."

Bai and his team calculated the thermodynamic properties of copper electrical bonds and used this information to construct so-called Pourbaix diagrams – maps of the immunity, passivity and corrosion zones of alloys with different copper and aluminum compositions in the presence of corrosive agents, such as water and chloride at various temperatures.

"We showed that the stability of the layer of aluminum oxide formed during bonding plays a critical role," says Bai. "By introducing highly charged atomic impurities into the aluminum pads, the diffusion of aluminum atoms out of the aluminum oxide can be reduced and thus, the stability can be enhanced." Therefore, this scheme offers one possible route to improving the reliability of copper bonds.

More information: Zeng, Y., Bai, K. & Jin, H. Thermodynamic study on the corrosion mechanism of copper wire bonding. *Microelectronics Reliability* 53, 985–1001 (2013).
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